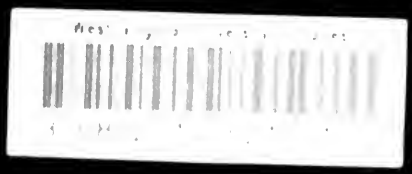

Bulletin 264 March, 1935

Copper Sulphate as an Anthelmintic for Gastro-Intestinal Parasites of Sheep

By J. H. RIETZ

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

Copper Sulphate as an Anthelmintic for Gastro-Intestinal Parasites of Sheep

By J. H. RIETZ

THE CONTROL of gastro-intestinal parasites has become one of the major problems confronting sheep husbandmen throughout much of the sheep-raising area of the United States.

In West Virginia the sheep ranges for the most part are permanently fenced pastures; consequently the sheep range over the same area year after year. This adds to the constant accumulation of infestation in the pastures and the likelihood of infestation in the sheep.

The object of this investigation was to find more effective methods of treatment for stomach worms and to observe the effect of the treatment upon the species of parastites infesting the intestinal tract.

In Table 1 are listed the names of the parasites encountered and identified during the investigation.

TABLE 1—*Parasites found one or more times during the experiment*

Scientific name	Popular name
Hoemonchus contortus	Stomach worm
Ostertagia sp.	Stomach worm
Oesophagostomum columbianum	Nodular worm
Bunostomum trigonocephalum	Hook worm
Trichuris ovis	Whip worm
Cooperia sp.	Hair worm
Nematodirus sp.	Hair worm
Chabertia ovina	
Moniezia expansa	Tape worm
Moniezia alba	Tape worm
Oestrus ovis larvae	Grubs
Dictyocaulus filaria	Lung worm
Synthetocaulus rufescens	Lung worm
Eimeria faurei	Coccidia
Cysticercus tenuicollis	Tapeworm cyst

EXPERIMENTS WITH FLOCK A

Manner of treating and handling

Thirty sheep that showed symptoms of advanced parasitism were numbered for identification and divided into two lots, I and II. The sheep in Lot I were drenched with 3 ounces of a 1 percent solution of copper sulphate; those in Lot II with 3 ounces of a 1½ percent solution of copper sulphate. Food was withheld from both lots for the 24-hour period before each treatment; it was not withheld from any of the sheep after drenching. Both lots were treated at intervals of 21 days throughout the period of the experiment, regardless of the season or feeding conditions.

Three untreated sheep were placed in the flock as controls.

ACKNOWLEDGMENT

Credit is due Dr. E. N. Moore of the West Virginia State Department of Agriculture, who assisted in carrying out the details of this work.

The range over which these sheep grazed consisted of approximately 12 acres, cross-fenced so that the closing of two gates provided three pastures of approximately four acres each. Ordinarily the sheep had the free range of the entire pasture, but occasionally they were confined to one of the small pastures. When the grass on the range became inadequate the pasture was supplemented with hay and grain, regardless of the season. This limited range assured pastures that were heavily infested with parasite larvae and ova.

The water supply was from a small stream that flowed through the three pastures.

Lots I and II and the control sheep were pastured and fed together as one flock unit, A, from July, 1930, until the termination of the experiment and the autopsy of the sheep. The last autopsy in Lots I and II occurred respectively in April and June, 1931.

Determination of parasite ova in the feces

A count of the nematode ova was made from the fecal deposit of each sheep before treatment was begun, and again two weeks after each treatment.

The method described by Stoll (*1*) for counting hookworm ova was used to determine the number of ova in the feces.

All sheep in Flock A were autopsied for a count of parasites remaining in the carcass.

TABLE 2—*Nematode ova count in feces of sheep in Lot I before treatment was begun and following the treatment* indicated*

Animal number	Number of treatments						
	0	3	6	8	11	12	13
12	600	1100					
39	350	400					
56	1000	1700					
58	12000	5000					
15	1500	400	400				
33	1050	200	200	500			
31	2000	50	150	50			
5	100	200	50	50			
34	150	100	100	200			
35	700	400	500	600			
54	4500	1000	100	0	50		
63	1000	300	100	3000	6000		
46	1500	1500	300	500	1000	1000	
65	1250	1250	500	500	500	700	
64	1250	850	400	100	100	100	150
Decrease		50%	81.2%	55.8%	21.7%	55%	88%

*Fasted 24 hours and treated with 3 ounces of a 1% solution of copper sulphat at intervals of 21 days.

Results of treatment

Tables 2 and 3 show the count of nematode ova in the feces of the sheep in Lot I before treatment was begun and after the third, sixth, eighth, eleventh, twelfth, and thirteenth treatment. The condition of the sheep and the manner of each species of parasite found at autopsy are also shown.

A comparison of the total ova count in the feces of sheep before treatment and after the last treatment just preceding autopsy,

TABLE 3—*Number of treatments* given the sheep in Lot I, the ova count before treatment and after the last treatment, the condition of the animal when slaughtered, and the species and number of parasites found at autopsy*

Animal number	Times treated	Reason for autopsy	Nematode ova count before treatment	Nematode ova count after last treatment	Parasites found at autopsy													Condition of animal at time of autopsy
					H. contortus	Ostertagia sp.	O. columbianum	B. trigonocephalum	T. ovis	Cooperia sp.	Nematodirus sp.	Chabertia ovina	Tapeworms	Tapeworm cysts	Lungworms	Oestrus ovis larvae	Coccidia	
12	3	Parasite count	600	1100	0	0	50	30	0	0	0	0	0	0	0	25	+	Fair stock condition
39	3	" "	350	400	0	0	0	46	0	0	0	0	0	1	0	0	+	Fair stock condition
56	3	" "	1000	1700	150	0	20	50	25	0	0	0	0	0	0	0	+	Poor stock condition
58	3	Killed by dogs	12000	5000	++	0	10	26	0	0	0	0	0	0	0	0	+	Emaciated
15	6	Parasite count	1500	400	No parasite count													Poor stock condition
33	8	" "	1050	500	30	0	0	20	0	3	0	0	0	0	0	0	+	Fair stock condition
31	8	" "	2000	50	12	0	0	0	0	0	0	0	0	0	0	0	+	Good stock condition
5	8	" "	100	50	6	0	0	0	0	0	0	0	0	0	0	0	+	Good stock condition
34	8	" "	150	200	40	0	0	10	0	0	0	0	0	0	0	0	+	Good stock condition
35	8	" "	700	600	25	0	10	25	0	0	0	0	0	0	0	0	+	Good stock condition
54	11	" "	4500	50	0	0	13	0	0	0	0	0	0	1	0	0	+	Good stock condition
63	11	" "	1000	6000	++	0	0	19	0	0	0	0	0	0	0	7	+	Emaciated
46	12	" "	1500	1000	150	0	160	6	0	0	0	0	0	0	0	0	+	Fair stock condition
65	12	" "	1250	700	0	0	25	10	0	50	0	0	0	1	0	4	+	Poor stock condition
64	13	" "	1250	150	10	0	1	1	0	0	0	0	0	0	0	1	+	Fair stock condition
Total			28950	17900	—				Decrease 38.1%									

++ Indicates too numerous to count.

+ Indicates present but not counted.

* Fasted 24 hours and treated with 3 ounces of a 1% solution of copper sulphate at intervals of 21 days.

shows a reduction of 38.1 percent in nematode ova during the period of treatment. If one sheep, No. 63, (see also Table 2) is eliminated from the experiment, the reduction in ova will be 71.7 percent. This animal did not respond to treatment but showed a marked increase in ova in its feces during the period of treatment.

Tables 4 and 5 show the count of nematode ova in the feces of the sheep in Lot II before treatment was begun and after the third, sixth, eighth, eleventh, twelfth, and thirteenth treatment. The condition of the sheep and the number of each parasite found at autopsy is also shown.

TABLE 4—*Nematode ova count in feces of sheep in Lot II before treatment and following the treatment* indicated*

Animal number	Number of treatments							
	0	3	6	8	11	12	13	16
19	650	50						
29	4600	700						
20	650	900	300	350				
21	200	0	50	0				
26	100	0	100	500				
6	900	100	200	700				
14	250	0	100	50				
37	1050	0	100	100				
45	1250	1700	150	50	0	0		
60	3000	50	50	50	50	50		
52	6000	7000	2500	1000	3000	7000	10000	
59	900	700	150	150	100	0	0	
51	15000	10000	1500	1000	250	300	150	350
53	1250	250	200	250	100	200	50	0
62	5000	5000	2000	500	150	150	100	50
Decrease		35.1%	79.4%	86.9%	88.7%	76.2%	43.2%	98.1%

* Fasted 24 hours and treated with 3 ounces of a 1½% solution of copper sulphate at intervals of 21 days.

TABLE 6—*Summary of the results of the treatment of sheep in Lots I and II*

Lot I Starved 24 hours before treatment; treated at intervals of 21 days with 3 ounces of a 1% solution of copper sulphate			Lot II Starved 24 hours before treatment; treated at intervals of 21 days with 3 ounces of a 1½% solution of copper sulphate		
Number of sheep treated	Number of times treated	% reduction of nematode ova	Number of sheep treated	Number of times treated	% reduction of nematode ova
15	3	50.0	15	3	35.1
11	6	81.2	13	6	79.4
10	8	55.8	13	8	86.9
5	11	21.7	7	11	88.7
3	12	55.0	7	12	76.2
1	13	88.0	5	13	43.2
			3	16	98.1

A comparison of the total ova count in the feces of the sheep before treatment and after the last treatment just preceding autopsy shows a reduction of 68.8 percent in nematode ova during the period of treatment.

If one sheep, No. 52 (see also Table 4), is eliminated from the experiment, the reduction in ova will be 91.7 percent. This animal, like No. 63 in Lot I, failed to respond to treatment and showed a marked increase in ova in the feces during the period of treatment.

TABLE 5—*Number of treatments* given the sheep in Lot II, the ova count before treatment and after the last treatment, the condition of the animal when slaughtered, and the species and number of parasites found at autopsy*

Animal number	Times treated	Reason for autopsy	Nematode ova count before treatment	Nematode ova count after last treatment	Parasites found at autopsy												Condition of animal at time of autopsy
					H. contortus	Ostertagia sp.	O. columbianum	B. trigonocephalum	T. ovis	Cooperia sp.	Nematodirus sp.	Chabertia ovina	Tapeworms	Tapeworm cysts	Lungworms	Oestrus ovis larvae	Coccidia	
19	3	Parasite count	650	50	0	0	0	10	0	0	0	0	0	0	0	10	0	Fair stock condition
29	3	" "	4600	700	0	0	40	0	0	0	0	0	0	1	0	0	+	Poor stock condition
20	8	" "	650	350	0	0	0	31	0	0	0	0	0	0	0	0	++	Good stock condition
21	8	" "	200	0	0	0	0	4	0	0	0	0	0	0	0	0	+	Good stock condition
26	8	" "	100	500	12	0	0	70	0	0	0	0	0	0	0	0	0	Good stock condition
6	8	" "	900	700	20	0	0	64	0	0	0	0	0	1	0	0	+	Fair stock condition
14	8	" "	800	50	0	0	0	28	0	0	0	0	0	0	0	0	++	Good stock condition
37	8	" "	1050	100	1	0	0	7	0	0	0	0	0	0	0	0	++	Good stock condition
45	12	" "	1250	0	0	0	0	0	0	0	0	0	0	0	0	0	++	Good stock condition
60	12	" "	3000	50	0	0	3	1	0	0	0	0	0	0	0	0	++	Good stock condition
52	13	Moribund	6000	10000	++	0	58	12	0	0	0	0	0	0	0	3	++	Emaciated
59	13	Parasite count	900	0	0	0	0	2	0	0	0	0	0	0	0	0	+	Good stock condition
51	16	" "	15000	350	50	0	1	30	0	0	0	0	0	0	0	0	+	Good stock condition
53	16	" "	1250	0	0	0	0	0	0	0	0	0	0	0	0	0	++	Fair stock condition
62	16	" "	5000	50	0	0	0	10	0	0	0	0	0	0	0	0	+	Good stock condition
Total			41350	12900	Decrease 68.8%													

++ Indicates too numerous to count. + Indicates present but not counted.

* Fasted 24 hours and treated with 3 ounces of a 1½% solution of copper sulphate at intervals of 21 days.

Tables 6 and 7 respectively show a summary of the results of the treatments of Lots I and II, and of the same lots with one sheep each, No. 63 of Lot I and No. 52 of Lot II, eliminated from the experiment. These two sheep did not respond to treatment and are responsible for the apparently inconsistent results shown in Table 6.

EXPERIMENTS WITH FLOCK B

Manner of treating and handling

Twenty-two sheep that showed symptoms of advanced parasitism were numbered for identification, divided into two lots of eleven each, and designated as Lots III and IV. The sheep in both lots were treated at intervals of 21 days with 4½ ounces of a 1 percent solution of copper sulphate. Those in Lot III were starved 24 hours before treatment, while those in Lot IV were not starved.

Twenty-seven sheep exhibiting symptoms of advanced parasitism were numbered for identification, and divided into two lots designated as Lots V and VI. The sheep in both lots were treated at intervals of 21 days with 3 ounces of a 1½ percent solution of copper sulphate. Sixteen sheep in Lot V were starved 24 hours before treatment, while the eleven sheep in Lot VI were not starved. Pasturing, feeding, and handling was the same as in Flock A.

TABLE 7—*Summary of the results of the treatment of sheep in Lots I and II, with sheep No. 63 of Lot I and sheep No. 52 of Lot II eliminated*

Lot I			Lot II		
Starved 24 hours before treatment; treated at intervals of 21 days with 3 ounces of a 1% solution of copper sulphate			Starved 24 hours before treatment; treated at intervals of 21 days with 3 ounces of a 1½% solution of copper sulphate		
Number of sheep treated	Number of times treated	% reduction of nematode ova	Number of times treated	Number of sheep treated	% reduction of nematode ova
14	3	49.5	14	3	44.1
10	6	80.7	12	6	83.1
9	8	80.0	12	8	87.0
4	11	80.7	6	11	96.6
3	12	55.0	6	11	96.5
1	13	88.0	4	13	98.9
			3	16	98.1

The sheep in Lots III, IV, V, and VI together with five untreated controls were pastured and fed together as one flock unit, B, from June, 1932, until autopsy or the termination of the experiment in August, 1933.

Results of treatment

Tables 8 and 9 show the count of nematode ova in the feces of the sheep in Lot III before treatment was begun and after the third, sixth, eleventh, thirteenth, seventeenth, and twenty-first treatments. There are shown also the condition of the sheep and the number of each species of parasite found at autopsy.

A comparison of the total ova count in the feces of the sheep before treatment and after the last treatment shows a reduction of 50.8 percent in nematode ova during the period of treatment.

TABLE 9—*Number of treatments* given the sheep in Lot III, the ova count before treatment and after the last treatment, the condition of the animal when slaughtered or at the termination of the experiment, and the species and number of parasites found at autopsy*

Animal number	Times treated	Reason for autopsy	Nematode ova count before first treatment	Nematode ova count after last treatment	Parasites found at autopsy													Condition of animal at time of autopsy or termination of experiment
					H. contortus	Ostertagia sp.	O. columbianum	B. trigonocephalum	T. ovis	Cooperia sp.	Nematodirus sp.	Chabertia ovina	Tapeworms	Tapeworm cysts	Lungworms	Oestrus ovis larvae	Coccidia	
46	6	Killed by dogs	5500	2100	No autopsy													Condition poor
49	6	Parasite count	200	0	0	0	0	0	0	0	0	0	0	0	0	0	+	Fair stock condition
54	6	" "	0	100	12	0	0	0	0	0	0	0	0	0	0	12	+	Fair stock condition
57	6	" "	100	0	0	0	0	0	0	0	0	0	0	0	0	0	+	Fair stock condition
55	11	Moribund	3400	3100	200	+	175	0	50	0	0	0	0	0	60	0	+	Emaciated
45	17	Living	800	0													++	Fat stock condition
50	17	"	3300	0													+	Fat stock condition
51	17	"	400	0													+	Fat stock condition
52	17	"	400	0													++	Fat stock condition
44	24	"	350	2400													++	Poor stock condition
48	24	"	600	700													+	Fair stock condition
Total			15050	8400	Decrease 50.8%													

\+ Indicates present but not counted.

* Fasted 24 hours and treated with 4½ ounces of a 1% solution of copper sulphate at intervals of 21 days.

Tables 10 and 11 show the count of nematode ova in the feces of the sheep in Lot IV before the treatment was begun and following the third, fourth, sixth, eighth, eleventh, thirteenth, seventeenth, and twenty-first treatments. Lot IV consisted of twelve

TABLE 8—*Nematode ova count in the feces of sheep in Lot III before treatment and following the treatment* indicated*

Animal number	Number of treatments							
	0	3	6	8	11	13	17	21
46	5500	1900	2100					
49	200	100	0					
54	0	0	100					
57	100	100	0					
55	3400	3000	3600	6300	3100			
45	800	300	600	1700	800	300	0	
50	3300	2000	1300	600	400	0	0	
51	400	—	400	400	900	400	0	
52	400	400	1400	2600	0	0	0	
44	350	400	600	200	1800	1500	2100	2100
48	600	600	1100	800	200	200	—	600
Increase or decrease		−40.8	−25.5	+36.2	−22.1	−58.9	−60.0	+184.0

* Fasted 24 hours and treated with 4½ ounces of a 1% solution of copper sulphate at intervals of 21 days.

TABLE 10—*Nematode ova count in the feces of sheep in Lot IV before treatment and following the treatment* indicated*

Animal number	Number of treatments								
	0	3	4	6	8	11	13	17	21
32	1500	200	—	—)					
1	100	300	0	—)					
2	1100	700	0	—)					
3	300	100	0	—)					
4	0	0	0	— (	yearling sheep				
5	100	300	0	—)					
6	0	0	0	—)					
7	100	0	0	—)					
26	300	200	0	—)					
27	1100	500	100	—)					
30	300	500	0	—)					
31	1000	200	200	—)					
22	3500	3600	—	3000	4500	2300	2300	1100	—
23	400	300	—	200	400	200	100	0	—
24	250	0	—	0	200	0	0	0	—
21	50	0	—	600	1000	400	600	100	300
Increase or decrease		−31.6%	−94.9%	−9.5%	+45.2%	−30.9%	−28.5%	−72.1%	+500%

* Treated with 4½ ounces of a 1% solution of copper sulphate at intervals of 31 days; not starved before treatment.

lambs and four adult sheep. The 12 lambs had been treated with a 1 percent solution of copper sulphate since an age of about 5 weeks, the dosage being increased gradually from one ounce at 5 weeks to 4½ ounces at 10 weeks. These lambs received only four treatments of 4½ ounces each.

The nematode ova count in the feces of the 12 lambs was reduced 91.3 percent during the period covered by the four treatments. The four adult sheep treated seventeen to 21 times showed a decrease of 66.6 percent in nematode ova during the period of treatment. The condition of the sheep and the number of each species of parasite found at autopsy also are shown.

TABLE 11—*Number of treatments* given the sheep in Lot IV, the ova count before treatment and after the last treatment, the condition of the animal when slaughtered or at the termination of the experiment, and the species and number of parasites found at autopsy*

Animal number	Times treated	Reason for autopsy	Nematode ova count before treatment	Nematode ova count after last treatment	Parasites found at autopsy													Condition of animal at time of autopsy or termination of experiment
					H. contortus	Ostertagia sp.	O. columbianum	B. trigonocephalum	T. ovis	Cooperia sp.	Nematodirus sp.	Chabertia ovina	Tapeworms	Tapeworm cysts	Lungworms	Oestrus ovis larvae	Coccidia	
32	3	Parasite count	1500	200	0	0	25	0	0	0	0	0	0	0	0	0	+	Fair stock condition
1	4	Living	100	0													+	Fat stock condition
2	4	"	1100	0													+	Fat stock condition
3	4	"	300	0													+	Fat stock condition
4	4	"	0	0													+	Fat stock condition
5	4	"	100	0													+	Fat stock condition
6	4	"	0	0													+	Fat stock condition
7	4	"	0	0													+	Fat stock condition
26	4	"	300	0													+	Fat stock condition
27	4	Parasite count	1100	100	0	0	30	9	0	0	0	0	0	0	0	0	+	Good stock condition
30	4	Living	300	0													+	Fat stock condition
31	4	"	1000	200													+	Good stock condition
22	17	"	3500	1100													+	Good stock condition
23	17	"	400	0													+	Good stock condition
24	17	"	250	0													+	Good stock condition
21	21	"	50	300													+	Good stock condition
Total			10100	1900	Decrease 81.1%													

+ Indicates present but not counted.

*Treated with 4½ ounces of a 1% copper sulphate solution at intervals of 21 days; not starved before treatment.

A comparison of the total ova count in the feces of the sheep before treatment and after the last treatment shows a reduction of 81.1 percent in nematode ova during the period of treatment.

TABLE 12—*Nematode ova count in the feces of sheep in Lot V before treatment and following the treatment* indicated*

Animal number	Number of treatments							
	0	3	6	8	11	13	17	21
36	0	0	100					
37	5300	600	0					
38	200	0	0					
39	400	400	200					
40	200	0	100					
42	100	100	0					
43	100	—	0					
71	23500	4800	300	200				
96	200	400	300	200				
70	2100	500	200	100	500			
97	16000	6200	1500	3200	500			
100	16400	5700	1300	2300	100			
41	0	—	400	200	300			
33	900	100	100	300	0	0	0	0
34	100	0	0	0	0	0	0	0
35	800	0	0	0	0	0	0	0
Decrease		71.6%	93.2%	89.1%	96.1%	100%	100%	100%

* Fasted 24 hours and treated with 3 ounces of a 1½% solution of copper sulphate at intervals of 21 days.

TABLE 14—*Nematode ova count in the feces of sheep in Lot VI before treatment and following the treatment* indicated*

Animal number	Number of treatments							
	0	3	6	8	11	13	17	21
12	600	1000						
9	9000	6000	600					
17	100	100	0					
19	50	0	0	0	0			
13	1100	900	3000	3100	1200			
10	200	200	700	700	100	300	—	200
11	1800	1300	1000	1900	400	0	—	100
14	50	0	100	100	400	0	—	200
16	200	300	1400	600	400	200	—	100
18	150	400	400	0	0	0	—	700
20	6100	2200	1100	300	400	800	—	500
Decrease		35.9%	54.0%	30.5%	69.9%	84.7%		78.9%

* Treated with 3 ounces of a 1½% solution of copper sulphate at intervals of 21 days; not fasted before treatment.

Tables 12 and 13 show the count of nematode ova in the feces of the sheep in Lot V before treatment was begun and following the third, sixth, eleventh, thirteenth, seventeenth, and twenty-first treatment. There is shown also the condition of the sheep and the number of each species of parasite found at autopsy.

A comparison of the total ova count in the feces of the sheep before treatment and after the last treatment shows a reduction of 96.6 percent in nematode ova during the period of treatment.

TABLE 13—*Number of treatments* given the sheep in Lot V, the ova count before treatment and after the last treatment, the condition of the animal when slaughtered or at the termination of the experiment, and the species and number of parasites found at autopsy*

Animal number	Times treated	Reason for autopsy	Nematode ova count before treatment	Nematode ova count after last treatment	Parasites found at autopsy													Condition of animal at time of autopsy or the termination of the experiment
					H. contortus	Ostertagia sp.	O. columbianum	B. trigonocephalum	T. ovis	Cooperia sp.	Nematodirus sp.	Chabertia ovina	Tapeworms	Tapeworm cysts	Lungworms	Oestrus ovis larvae	Coccidia	
36	6	Parasite count	0	100	0	0	0	5	0	0	0	0	0	0	0	0	+	Fair stock condition
37	6	" "	5300	0	0	++	0	0	0	0	0	0	0	0	0	0	++	Fair stock condition
38	6	" "	200	0	0	+	0	4	0	0	0	0	0	0	0	0	++	Poor stock condition
39	6	" "	400	200	0	0	0	6	0	0	0	0	0	0	0	0	++	Fair stock condition
40	6	" "	200	100	0	0	0	4	0	0	0	0	0	0	0	0	++	Poor stock condition
42	6	" "	100	0	0	0	0	0	0	0	0	0	0	0	0	0	+	Good stock condition
43	6	" "	100	0	0	0	0	0	0	0	0	0	0	0	0	0	+	Good stock condition
71	8	Living	23500	200													++	Poor stock condition
96	8	"	200	200													++	Fair stock condition
70	11	"	2100	500													++	Fair stock condition
97	11	"	16000	500													++	Fair stock condition
100	11	"	16400	100													++	Fair stock condition
41	11	"	0	300													++	Good stock condition
33	21	"	900	0													++	Fair stock condition
34	21	"	100	0													++	Good stock condition
35	21	"	800	0													++	Good stock condition
Total			66300	2200	Decrease 96.6%													

+ Indicates present but not counted.

* Fasted 24 hours and treated with 3 ounces of a 1½% solution of copper sulphate at intervals of 21 days.

TABLE 15—*Number of treatments* given the sheep in Lot VI, the ova count before treatment and after the last treatment, the condition of the animal when slaughtered or at the termination of the experiment, and the species and number of parasites found at autopsy*

Animal number	Times treated	Reason for autopsy	Nematode ova count before treatment	Nematode ova count after last treatment	Parasites found at autopsy													Condition of animal at the time of autopsy or the termination of the experiment
					H. contortus	Ostertagia sp.	O. columbianum	B. trigonocephalum	T. ovis	Cooperia sp.	Nematodirus sp.	Chabertia ovina	Tapeworms	Tapeworm cysts	Lungworms	Oestrus ovis larvae	Coccidia	
12	3	Myasis	600	1000	12	+	++	26	0	0	0	0	0	0	0	0	+	Emaciated
9	6	Moribund	9000	600	100	++	++	6	10	50	20	0	0	0	0	0	+	Emaciated
17	6	Parasite count	100	0	0	0	4	1	0	0	0	0	0	0	0	0	+	Poor stock condition
19	11	Killed by dogs	50	0	0	0	0	0	0	0	0	0	0	0	0	0	+	Poor stock condition
13	11	Moribund	1100	1200	10	+	++	25	+	10	15	0	0	0	0	0	+	Emaciated
10	21	Living	200	200														Fat stock condition
11	21	"	1800	100														Fat stock condition
14	21	"	50	200														Fat stock condition
16	21	"	200	100														Fat stock condition
18	21	"	150	700														Fat stock condition
20	21	"	6100	500														Fat stock condition
Total			19350	4600				Decrease 76.2%										

++ Indicates too numerous to count. + Indicates present but not counted.

* Treated with 3 ounces of a 1½% solution of copper sulphate at intervals of 21 days; not fasted before treatment.

Tables 14 and 15 show the count of nematode ova in the feces of the sheep in Lot VI, before treatment was begun and after the third, sixth, eleventh, thirteenth, and twenty-first treatment. There is also shown the condition of the sheep and the number of each species of parasite found at autopsy.

A comparison of the total ova count in the feces of the sheep before treatment and after the last treatment shows a reduction of 76.2 percent in nematode ova, during the period of treatment.

TABLE 16—*Summary of results of treatment of sheep in Lots III and IV*

Lot III treated with 4½ ounces of a 1% copper sulphate solution; starved 24 hours before treatment			Lot IV treated with 4½ ounces of a 1% copper sulphate solution; not starved before treatment		
Number of sheep treated	Number of times treated	% reduction of nematode ova	Number of sheep treated	Number of times treated	% reduction of nematode ova
11	3	40.8	16	3	31.6
11	6	25.5	4	6	9.5
7	8	+36.2	4	8	+45.2
7	11	22.1	4	11	30.9
6	13	58.9	4	13	28.5
5	17	+60.0	4	17	72.1
2	21	+184.0	1	21	+500.0

TABLE 17—*Summary of results of treatment of sheep in Lots V and VI*

Lot V treated with 3 ounces of a 1½% solution of copper sulphate; starved 24 hours before treatment			Lot VI treated with 3 ounces of a 1½% solution of copper sulphate; not starved before treatment		
Number of sheep treated	Number of times treated	% reduction of nematode ova	Number of sheep treated	Number of times treated	% reduction of nematode ova
16	3	71.6	11	3	35.9
16	6	93.2	10	6	54.0
9	8	89.1	8	8	30.5
7	11	96.1	8	11	69.9
4	13	100	6	13	84.7
4	17	100	6	17	Not taken
4	21	100	6	21	78.9

Table 16 shows a comparison of the results of treatment in the increase or decrease of nematode ova in the feces of sheep in Lot III, which were starved before treatment, and in Lot IV, which were not starved before treatment. Both lots were treated at intervals of 21 days, with 4½ ounces of a 1% solution of copper sulphate.

Table 17 compares the results of treatment in the increase or decrease of nematode ova in the feces of sheep in Lot V, starved before treatment, and Lot VI, not starved before treatment. Both lots were treated at intervals of 21 days with 3 ounces of a 1½% solution of copper sulphate.

Table 18 shows the record of the untreated control sheep that were kept for varying periods of time in the pastures with the copper-sulphate treated sheep of Flocks A and B. The control sheep were chosen because they showed a low ova count in the feces or were in better condition than the sheep selected for treatment. If we compare the total count of ova in the feces of the

controls at the beginning of the experiment with the ova count just preceding autopsy, it will be found that there was an increase of 1240% in nematode ova during the period of time they were in the Flocks A and B. There are shown also the condition of the sheep at the time of autopsy and the number of each species of nematode found at autopsy.

Control animal No. 43 was killed by dogs just 12 weeks after being placed in the flock. Animal No. 47 was in the flock 44 weeks. These animals were the extremes in period of time the controls lived in the flocks.

SUMMARY

In Table 19 is shown the average percentage of efficiency in reducing nematode ova in the feces of the sheep in Flocks A (Lots I and II) and B (Lots III, IV, V, and VI).

Fourteen sheep that had been prepared for treatment by starving 24 hours were given an average of 8.15 treatments, with 3 ounces of a 1 percent solution of copper sulphate. This resulted in a 71.7 percent reduction in nematode ova during the period of treatment. One sheep, No. 63, was omitted from these calculations because the animal did not respond to treatment and is not representative of the action of copper sulphate as an anthelmintic.

Eleven sheep that had been prepared for treatment by starving 24 hours were given an average of 14 treatments, with 4½ ounces each of a 1 percent solution of copper sulphate. There was a reduction of 50.8 percent in nematode ova in this group during the period of treatment.

Four sheep, adults that were not starved before treatment, received an average of 18 treatments of 4½ ounces each of a 1 percent solution of copper sulphate. There was a reduction of 66.6 percent in the nematode ova in this group during the period of treatment.

Twelve sheep, yearlings that were not starved before treatment, were given four treatments of 4½ ounces each of a 1 percent solution of copper sulphate. A reduction was noted of 91.3 percent in the nematode ova in this group during the period of treatment.

Sixteen sheep, adults and yearlings, not starved before treatment, were given an average of 7.45 treatments of 4½ ounces each of a 1 percent solution of copper sulphate. There was a reduction of 81.1 percent in nematode ova in this group during the period of treatment.

Eleven sheep that were not starved before treatment were given an average of 14.8 treatments of 3 ounces of a 1½ percent solution of copper sulphate. There was a reduction of 76.0 percent in nematode ova in this group during the period of treatment.

TABLE 18—*Record of the untreated control sheep pastured and fed with the copper-sulphate treated sheep*

Animal number	Times treated	Reason for autopsy	Nematode ova count when placed in flock as controls	Nematode ova count before autopsy	Parasites found at autopsy													Condition of sheep when autopsied
					H. contortus	Ostertagia sp.	O. columbianum	B. trigonocephalum	T. ovis	Cooperia sp.	Nematodirus sp.	Chabertia ovina	Tapeworms	Tapeworm cysts	Lungworms	Oestrus ovis larvae	Coccidia	
47	0	Moribund	0	11700	++	0	500	79	0	0	0	268	2	0	50	0	+	Emaciated
53	0	"	0	1400	200	0	50	0	10	0	0	0	1	0	0	0	+	Emaciated
56	0	Killed by dogs	50	2800	100	0	125	14	0	0	0	0	0	0	0	0	+	Poor condition
57	0	Moribund	100	1050	150	0	100	0	0	0	0	0	0	0	6	0	+	Emaciated
66	0	Killed by dogs	700	1200	400	0	18	9	0	0	0	0	4	0	0	0	+	Poor condition
32	0	Parasite count	100	1500	200	0	0	0	0	0	0	0	0	1	0	0	+	Fair condition
43	0	Killed by dogs	800	1100	150	0	50	5	0	0	0	0	1	0	0	0	+	Fair condition
44	0	Parasite count	0	2700	250	0	10	25	5	0	0	1	0	0	0	0	+	Fair condition
Total ova			1750	23450	Increase of 1240%													

++ Indicates too numerous to count.

+ Indicates present but not counted.

TABLE 19—*Summary of the percentage of efficiency of copper sulphate in reducing the nematode ova in sheep feces*

Lot number	Number of sheep	Preparation	Anthelmintic	Percent solution	Dose	Average number of treatments	Percentage efficiency	Remarks
I	15	Starved	$CuSO_4$	1%	3 oz.	8.2	38.1	
I	14	Starved	$CuSO_4$	1%	3 oz.	8.15	71.7	If one sheep, No. 63, is eliminated from Lot I
II	15	Starved	$CuSO_4$	1½%	3 oz.	10.15	68.8	
II	14	Starved	$CuSO_4$	1½%	3 oz.	9.2	91.7	If one sheep, No. 52, is eliminated from Lot II
III	11	Starved	$CuSO_4$	1%	4½ oz.	13.7	50.8	
IV	4	Not starved	$CuSO_4$	1%	4½ oz.	18	66.6	Adult sheep
IV	12	Not starved	$CuSO_4$	1%	4½ oz.	4	91.3	Yearling sheep
IV	16	Not starved	$CuSO_4$	1%	4½ oz.	7.45	81.1	Average of adults and yearlings in Lot IV
V	16	Starved	$CuSO_4$	1½%	3 oz.	11.6	96.6	
VI	11	Not starved	$CuSO_4$	1½%	3 oz.	14.8	76.2	
II-V	31	Starved	$CuSO_4$	1½%	3 oz.	7.3	85.9	
II-V	30	Starved	$CuSO_4$	1½%	3 oz.	7.1	94.9	If one sheep, No. 52, is eliminated from Lot II

Thirty sheep that had been prepared for treatment by starving 24 hours were given an average of 7.1 treatments of 3 ounces each of a 1½ percent solution of copper sulphate. There was a reduction of 94.9 percent in nematode ova in this group during the period of treatment. One sheep, No. 52, was omitted from these calculations because this animal did not respond to treatment and is not representative of the action of copper sulphate as an anthelmintic.

THE EFFECT OF COPPER SULPHATE UPON INTESTINAL PARASITES OF SHEEP

Cestodes (Tapeworms)

Only 47 of the sheep treated with copper sulphate were autopsied. Three sheep of this group showed one small immature tapeworm each. These three sheep belonged to the group treated with the 1 percent solution. Of the eight untreated control sheep, four showed tapeworms at autopsy. There were seven large mature parasites and one small immature one.

Bunostomum trigonocephalum (Hookworm)

Hookworms were found at autopsy in 62.5 percent of the untreated control animals and in 68.1 percent of the treated animals. The average number of parasites per host for the untreated control group was 16.5, and for the treated group, 12.7.

Oesophagostomum columbianum (Nodularworm)

Nodular worms were found at autopsy in 87.5 percent of the untreated control animals and in 40.4 percent of the treated animals. The parasites in three of the treated sheep were not counted but were estimated at about 500 each. The average number of parasites per host for the untreated control group was 102.8, and for the treated group, 46.8.

Trichuris ovis (Whipworms)

Whipworms were found only in two of the control animals and in three of the treated animals. Consequently in view of the small number of animals involved no comparison is made.

OTHER ANTHELMINTICS

During the progress of this series of treatments a few sheep were treated with (1) 3 ounces of 1½ percent nicotine sulphate; (2) 3 ounces of a mixture of equal parts 1½ percent nicotine sulphate and 1½ percent copper sulphate solution; (3) 5 c.c. of tetrachlorethylene; (4) 20 c.c. of colloidal iodine (Merck); and (5) calcium polysulphite. These sheep were pastured and fed with the flocks that were treated with the copper sulphate solution.

The results of autopsy and the count of the ova in the feces indicate that none of these preparations is superior in effectiveness to the 1½ percent solution of copper sulphate, and some of them were less effective in eliminating gastro-intestinal parasites from sheep.

Calcium polysulphite was used as the anthelmintic in a considerable number of sheep. The dosage was varied from 1 ounce to 12 ounces of a 1 percent solution to a 1 ounce to 2½ ounces of a 12 percent solution. A 6-ounce dose of a 1½% solution was found effective in causing a reduction in the nematode ova in the feces, but calcium polysulphite in all dilutions used caused nausea in many of the sheep. Dilutions as low as 1½ percent were irritating to the mucous membrane of both the stomach and intestines, and the sheep failed to regain flesh properly. Dilutions of 2½ percent or more were toxic under certain conditions and caused the death of a few of the sheep.

EFFECT OF STARVING UPON THE PROPER DELIVERY OF THE ANTHELMINTIC TO THE ABOMASUM

Sixteen sheep in this experiment were drenched with 3 ounces of dye solution (Rhodamin B) just before slaughter. These sheep were not starved before drenching. The autopsies showed that all the dye had passed to the abomasum in only five sheep. In five sheep the entire dose of dye entered the rumen. In five sheep the solution was found in the rumen and reticulum. In one sheep it was found in the rumen, reticulum, and omasum.

Six sheep in this experiment were starved 24 hours and drenched with 3 ounces of the dye solution just before slaughter. The autopsies showed that all the solution had passed to the abomasum in two sheep. The larger part had passed to the abomasum in the other four sheep, but a trace of red was present in the rumen in one sheep, rumen and reticulum in one sheep, reticulum and omasum in one sheep, and omasum in one sheep.

If the results of these few trials can be accepted as indicative, it may explain why certain individuals fail wholly or partially to respond to treatment. In those sheep that give only partial or no response, probably the drench solution passed in part or in its entirety to the rumen or compartment other than the abomasum.

DISCUSSION

If we study and compare the results of treatment of sheep in Lot I, as shown in Tables 2 and 3, and Lot II, as shown in Tables 4 and 5, it will be found that four sheep in Lot I were free from *Hoemonchus contortus* (stomach worms) and four sheep retained a considerable number of these parasites. The remaining seven sheep each showed a few of these parasites. There was an average of 38.1 percent reduction in nematode ova in the feces of the sheep in Lot I at the time of autopsy.

Lot II shows ten sheep free from *Hoemonchus contortus* and one sheep retaining a considerable number of these parasites. The remaining four sheep each showed a few of these parasites. There

was an average of 68.8 percent reduction of the nematode ova in the feces of the sheep in Lot II at the time of autopsy.

One sheep in each lot showed a marked increase in the nematode ova in the feces at the last fecal examination before autopsy. These two sheep caused the low efficiency of the copper-sulphate solution in each lot. (See Tables 6 and 7).

The general condition of the two lots was practically alike at the beginning of treatment. If any difference existed, Lot I may have been in slightly better condition than Lot II.

At the time of autopsy Lot I showed five sheep in good condition, five sheep in fair condition, three sheep in poor condition, and two emaciated sheep. Lot II showed ten sheep in good condition, three sheep in fair condition, one sheep in poor condition, and one emaciated sheep.

If we compare the results of treatment of the sheep in Lot III, as shown in Tables 8 and 9, and Lot IV as shown in Tables 10 and 11, it will be found that only four sheep in Lot III have been autopsied. Two sheep were found free of *Hoemonchus contortus* and one retained a considerable number and one a few of these parasites. There was an average of 50.8 percent reduction in the nematode ova in the feces of the sheep in Lot III at the time of autopsy or the termination of the experiment.

Lot IV consisted of 12 lambs and four adult sheep. Treatment of the lambs was begun at five to six weeks of age and continued at intervals of 21 days, with gradually increasing dosage, until about ten months of age, when they were receiving the adult dose of 4½ ounces. These 12 lambs (yearlings) were transferred to another experiment when about 13 months of age, having been given only four treatments of 4½ ounces each.

The 12 yearlings show an average reduction of 91.3 percent in the nematode ova in their feces, while the four adults show only 66.6 percent reduction.

At the time of autopsy or termination of the experiment Lot III showed four sheep in fat condition, four in fair condition, two in poor condition, and one emaciated. Lot IV showed nine sheep in fat condition, six in good condition, and one in fair condition.

If we compare the results of treatment of the sheep in Lot V, as shown in Tables 12 and 13, and Lot VI, as shown in Tables 14 and 15, it will be found that seven sheep in Lot V have been autopsied and all seven were free from *Hoemonchus contortus*. There was an average reduction of 96.6 percent in nematode ova in the feces of the sheep in Lot V at the time of autopsy or termination of the experiment.

Only five sheep were autopsied from Lot VI. Two of these sheep were found free of *Hoemonchus contortus* and one retained a considerable number and two a few parasites.

There was an average reduction of 76.2 percent in nematode ova in the feces of the sheep in Lot VI at the time of autopsy or the termination of the experiment. At this time the sheep in Lot V showed five sheep in good condition, eight in fair condition, and three in poor condition. Lot VI showed six sheep in fat condition, two in poor condition, and three emaciated.

A careful analysis of Tables 8, 9, 12, and 13 indicates that there was little or no decrease in nematode ova in the feces of many of the sheep and an actual increase in some of the sheep for a period centering about the time of the eighth treatment of the sheep in Flock B. During a period before and after this time the pasture was exhausted and the quality of the hay was poor. A decrease in the ova count resulted soon after the resumption of feeding of good hay, which in this case was alfalfa.

This increase in nematode ova is also shown in the average figures in Tables 16 and 17.

The ova count in the feces throughout this examination apparently was influenced adversely by the reduction in the quality of the feed.

CONCLUSIONS

Withholding all food for a period of 24 hours before drenching ment increased the efficiency of the anthelmintic in the sheep used in these trials.

Withholding all food for a period of 24 hours before drenching sheep apparently influenced the passage of the drench solution to the abomasum.

A 1½ percent solution of copper sulphate was the most effective anthelmintic used against stomach worms in the sheep reported in these treatments.

A 1½ percent solution of copper sulphate was effective in removing tapeworms from the intestines of the sheep used in these trials, when regularly and systematically administered.

Regular and systematic treatment of sheep at intervals of 21 days with a 1½ percent solution of copper sulphate reduced the intestinal nematode infestation in the sheep used in these trials.

No ill effect was noted from the use of a 1½ percent solution of copper sulphate as used in these trials.

Feeding of good food in proper quantities is an essential factor in the successful use of anthelmintics (copper sulphate) in the elimination of gastro-intestinal parasites from sheep.

REFERENCE

(1) Stoll, N. R.

1923. Investigations on the Control of Hookworm Disease: XV. An Effective Method of Counting Hookworm Eggs in Feces. Am. Jour. Hyg. *3*: 59-70.